Overview of Standard Setting and Incremental Techniques
Souhegan River Technical Review Committee
March 22, 2004

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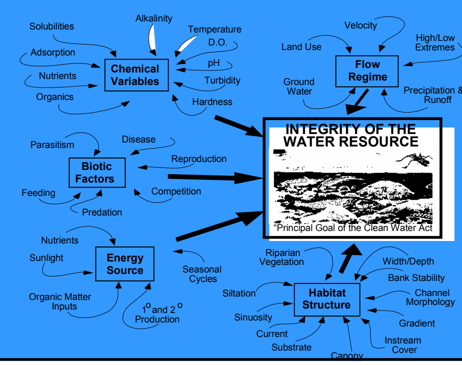
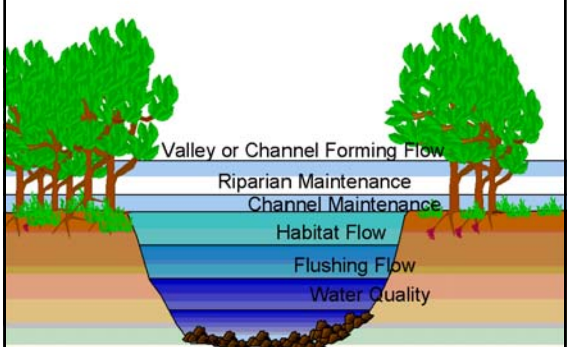
The Five Major Factors Which Determine the Integrity of Aquatic Resources



Different Flows Perform Different Functions…



From Chisholm 2000

CONNECTIVITY

Instream Flow Applications Should Address 5 Ecosystem Components:

- Hydrology (magnitude, frequency, duration, timing, rate of change)
- Geomorphology (channel process, sediment transport)
- Biology (habitat, population relationships)
- Water Quality (temperature, dissolved oxygen, contaminants, etc)
- Connectivity (pathways for water, organisms, energy)

Flow management is inter-disciplinary

Instream Flow Assessment Tools

Hydrology	IHA, RVA
Geomorphology	Channel Maintenance, Flushing Flow Empirical, Geomorphic Classification, HEC-6, HEC-RAS
Biology	2-Dimensional Models, Aquatic Base Flow, Biological Response Regressions, Feeding Station, Flow Duration Curve Methods, IBI, PHABSIM, Plunge Pool, RCHARC, R2-CROSS, Tennant, Toe Width, Wetted Perimeter
Water Quality	QUAL2E, SS/SNTEMP, TMDL, 7Q10
Connectivity	Floodplain Innundation, Migration Cue, Salmon Barrier, Tidal Distributary/Estuary
Multiple Component	Demonstration Flow Assessment, Florida Spring Flow, IFIM

(Instream Flow Council 2001)

Two Ways of Setting Flow Targets (Stalnaker, 1995)

- Standard Setting
- Low controversy project
- Reconnaissance-level planning
- Few decision variables
- Inexpensive
- Fast
- Rule-of-thumb
- Less scientifically accepted
- Not well-suited for bargaining

- Incremental
- High controversy project
- Project-specific
- Many decision variables
- Expensive
- Lengthy
- In-depth knowledge required
- More scientifically accepted
- Designed for bargaining
- Based on fish or habitat

Types of Instream Flow Assessment tools

Tool	Description	Examples
Baseline	Establishes environmental or reference conditions	RVA IBI, IHA
Standard-setting	Sets limits or rules to define a flow regime	Tennant ABF, Wetted Perimeter R2-Cross
Incremental	Analyzes single or multiple variables to enable assessment of different flow management alternatives	IFIM, PHABSIM,MESOHABSIM RCHARC, SNTEMP Demonstration Flow Assessment
Monitoring / Diagnostic	Assesses conditions and how they change over time	IBI, HQI, IHA

(Instream Flow Council 2001)

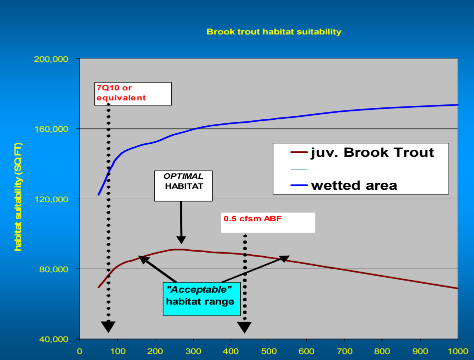
Standard Setting Approach

- ***Quickly generates a single point threshold***
- No predictive function
- Based on relatively generic information
- Does not support negotiated solutions
- resulting standards are not site-specific

Incremental Approach

- ***Quantifies both habitat and water use trade-of[f] alternatives across a spectrum of flows***
- Predicts a range of effects rather than only one
- Based on scientific and site-specific input
- Supports negotiated solutions
- takes longer than Standard Setting approach

Incremental *vs.* Standard Setting



ASSESSMENT OF HABITAT, FISH COMMUNITIES, AND STREAM FLOW REQUIREMENTS FOR HABITAT PROTECTION, IPSWICH RIVER, MASSACHUSETTS, 1998-99

Several standard-setting instream flow methods were compared.

1. Tennant Method
2. Aquatic Base Flow (ABF) Method
3. Wetted Perimeter Method
4. R2CROSS Method
5. Range of Variation Approach (RVA)

Streamflow data for the Tennant and ABF methods and the Range of Variation Approach (RVA) were determined from HSPF model simulations for streamflow with no-withdrawals and 1991 land use (Zarriello and Ries, 2000). The Tennant and R2CROSS methods require field data collection at riffles.

Tennant Method

- Seasonal periods based on western hydrology
- Habitat-flow relationship not verified for northeast
- Can include flushing flows but does not address channel maintenance

Tennant Method

Recommended Base Flow Regimens				
	October - March		April - September	
Health of Habitat	% of AAF	Equivalent VT cfs/sq. mi. Value	% of AAF	Equivalent VT cfs/sq. mi. Value
Flushing Flow	200%	3.5	200%	3.5
Optimum	60-100%	1.1 - 1.8	60-100%	1.1 - 1.8
Outstanding	40%	0.7	60%	1.1
Excellent	30%	0.5	50%	0.9
Good	20%	0.35	40%	0.7
Fair	10%	0.2	30%	0.5
Poor	10%	0.2	10%	0.2
Severe Degradation	<10%	<0.2	<10%	<0.2
Note: The statewide average annual flow in Vermont is 1.77 cfs/sq. mi.				

Aquatic Base Flow

- Uses hydrologic statistic as a surrogate for aquatic habitat
- Office technique used to sustain habitat during low flow season
- Median August flow set as the minimum flow
- Seasonal ABF adds the April/May median for spawning and February median for fall/winter flows
- Habitat dynamics, connectivity and floodplain integrity ignored

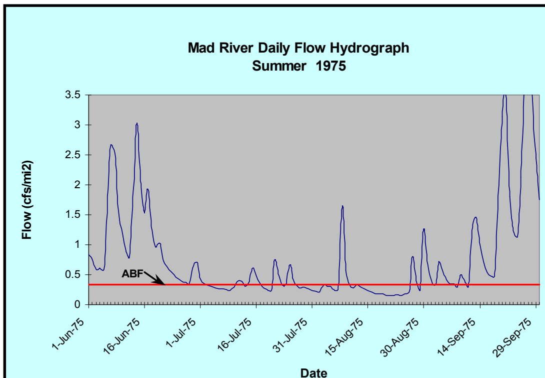
New England Aquatic Base Flow (ABF) Method

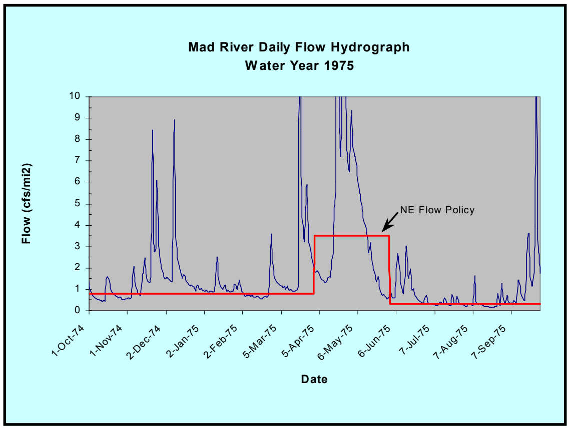
- **Recommends the August median flow and where applicable, seasonal median flows for spawning and incubation**
- **For rivers lacking adequate gage data, "default" regional average values are used or site specific studies may be done.**

Season	Period	Median Flow Standard	Default (cfs/mi^2)
Fall/winter	Oct 1 - Mar 31	February	1.0
Spring	Apr 1 - May 31	April/May	4.0
Summer	Jun 1 - Sep 30	August	0.5

New England Aquatic Base Flow (ABF) Method

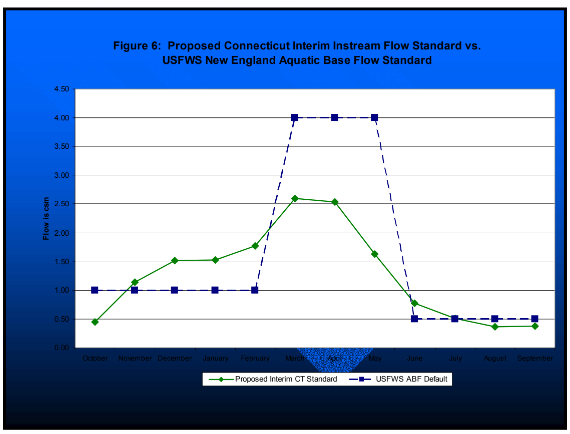
- Assumptions:
  - Aquatic life has evolved to survive "typical" low flows August
  - Historical median of monthly mean flows during spawning and incubation periods will protect reproduction
  - Gage records come from 48 gaged watersheds where flow is unregulated, larger than 50 SM and 25 years of record





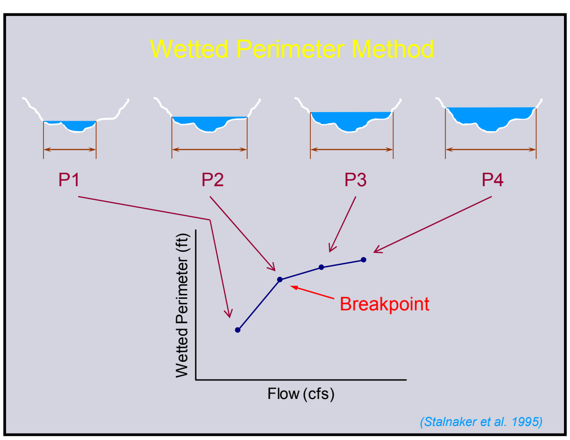
Apse Connecticut "ABF" Method

- Selected 10 Connecticut rivers which are wholly unregulated or slightly regulated
- At least 30 years of record
- Watershed areas between 4.1 and 203 square miles
- Calculate monthly numbers using FWS approach for Jul.-Sept. (median of monthly means)/ median of daily for Oct.-June)



Wetted Perimeter

- Assumes that adequate habitat is provided by the flow that wets the channel bottom and begins to rise up the banks
- Wetted perimeter in riffles is graphed versus flow
- The "breakpoint" on the graph is the flow recommendation



Wetted Perimeter

- Site-specific; moderate field effort
- No gage data required
- Selection of the breakpoint can be subjective
- Selection of transect site is critical; level of protection can vary
- Application of a single flow does not maintain hydrologic variability
- Habitat dynamics, channel processes, connectivity and floodplain integrity ignored

R2-Cross, or Habitat Retention Method

- **Habitat is assessed based on hydraulic criteria measured in the shallowest portion of stream riffles. The flow that meets these criteria is assumed to be adequate in non-riffle areas as well.**
- **Hydraulic models are generally used to predict these criteria over a range of flows.**

Stream Width (ft)	Average Depth (ft)	Average Velocity (fps)	% Wetted Perimeter
1-20	0.2	1.0	50
21-40	0.2 - 0.4	1.0	50
41-60	0.4 - 0.6	1.0	50 - 60
61-100	0.6 - 1.0	1.0	70

R2-Cross, or Habitat Retention Method

- Moderate field work required
- No gage data required
- Application of a single flow does not maintain hydrologic variability
- Habitat dynamics, channel processes, connectivity and floodplain integrity ignored

Hydrologic Standards

- Hydrologic statistics used as surrogate for aquatic habitat
- Inexpensive and easy to use
- Often focus only on a minimum flow
- Habitat dynamics, channel processes, connectivity and floodplain integrity ignored
- Not site-specific; level of resource protection varies
- Altered watersheds will yield altered gage data

Indicators of Hydrologic Alteration

- Uses hydrologic records to quantify change
- Office technique useful for monitoring change
- Used to pinpoint aspects of the hydrologic regime deviating significantly from the natural hydrograph

Indicators of Hydrologic Alteration

- Define gaging data series (pre- vs. post)
- Calculates values for each of 32 ecologically-relevant hydrologic attributes.
- Examples: frequency and duration of high and low pulses, magnitude and duration of annual extreme water conditions
- Compute inter-annual statistics. Compute measures of central tendency and dispersion for each of 32 attributes
- Calculate values of the Indicators of Hydrologic Alteration

Summary of hydrologic parameters used in the Index of Hydrologic Alteration, and their characteristics.

•Magnitude of Monthly Magnitude Mean value for each calendar month

•Water Conditions Timing

•Magnitude and Duration of Magnitude Annual minima 1-day means

•Annual Extreme Water Duration Annual maxima 1-day means

•Conditions Annual minima 3-day means

Summary of hydrologic parameters used in the Index of Hydrologic Alteration, and their characteristics.

•Annual maxima 3-day means
•Annual minima 7-day means
•Annual maxima 7-day means
•Annual minima 30-day means
•Annual maxima 30-day means
•Annual minima 90-day means
•Annual maxima 90-day means

•Timing of Annual Extreme Timing Julian date of each annual 1-day maximum

•Water Conditions Julian date of each annual 1-day minimum

•Frequency and Duration of Magnitude # of high pulses each year

•High/Low Pulses Frequency # of low pulses each year

Summary of hydrologic parameters used in the Index of Hydrologic Alteration, and their characteristics.

•Duration mean duration of high pulses within each year

•Mean duration of low pulses within each year

•Rate/Frequency of Water Frequency means of all positive differences between

•Consecutive Condition Changes Rate of change daily values

•Means of all negative differences between
•Consecutive daily values

•# of rises
•# of falls

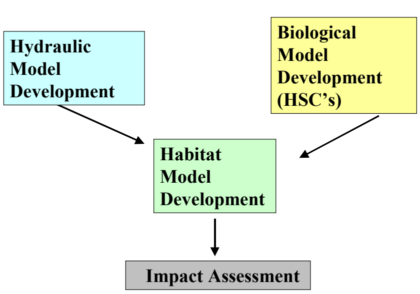
Standard Setting Cautions

- Standards are policy choices
- Standards are approximate and so must be resource-conservative
- Standards must address more than just minimum flows. A flat-line flow regime does not maintain river health
- Standards should consider the 5 ecosystem components (water quality, hydrology, biology, geomorphology, connectivity)
- Standards should consider the need for intra- and inter-annual flow variability

Instream Flow Incremental Methodology (IFIM)

- Determines effects of incremental changes in stream flow on:
  - Depth
  - Velocity
  - Substrate
  - Cover
- Relates effects of changes in physical components of habitat to suitability of these changes for various fish species

Components of IFIM

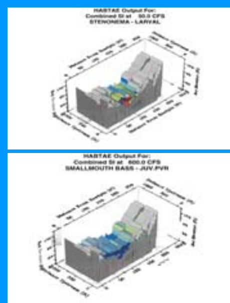


Physical Habitat Simulation *(P-HAB-SIM)*

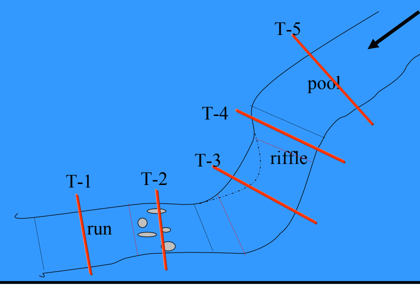
- Developed by USFWS to support IFIM-type analyses
- A physical model of stream hydraulics and habitat
- quantitatively relates changes in stream flow to habitat suitability
- Data should be used to inform incremental approach but no[t] be slavishly adhered to

What goes into a PHABSIM model?

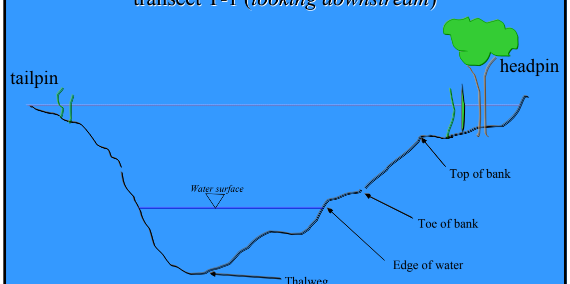
- Physical features of stream channel
- Hydraulic simulation of depth, velocity and wetted area
- Habitat use rating criteria
- Best results occur from comprehensive scoping



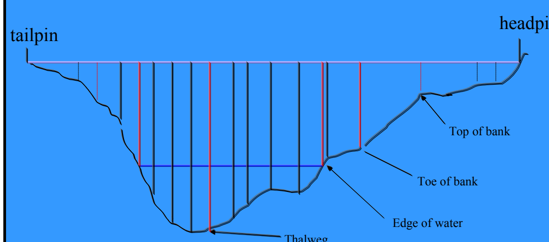
One transect is located within each longitudinal cell



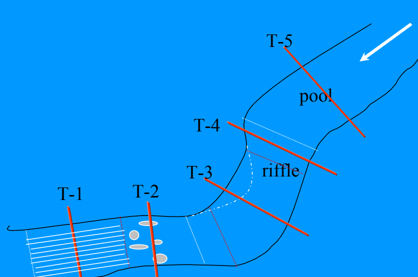
transect T-1 (*looking downstream*)



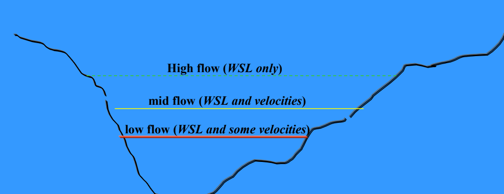
Verticals are located along each transect to capture key substrate and profile features

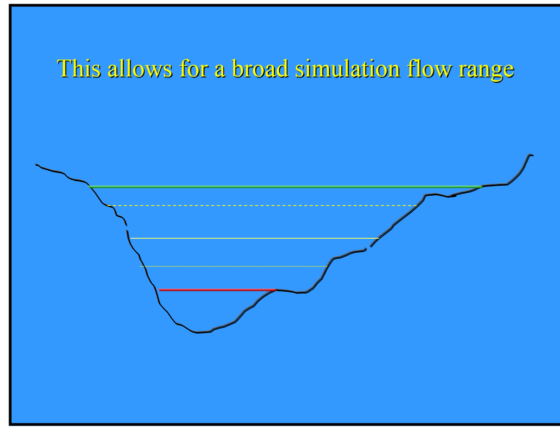


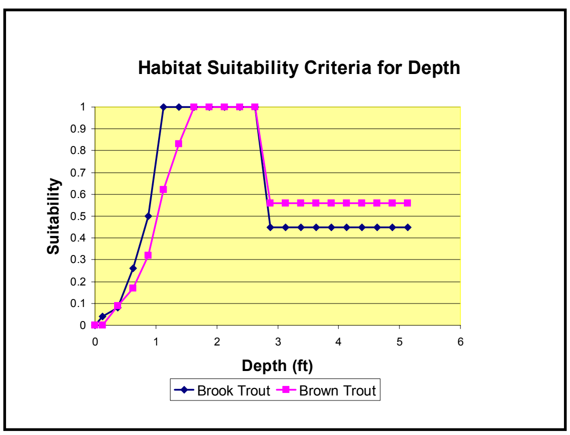
Verticals and cell boundaries act to divide each segment into a mosaic of known areas

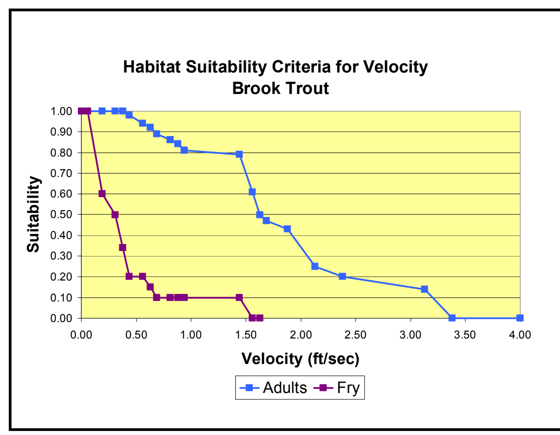


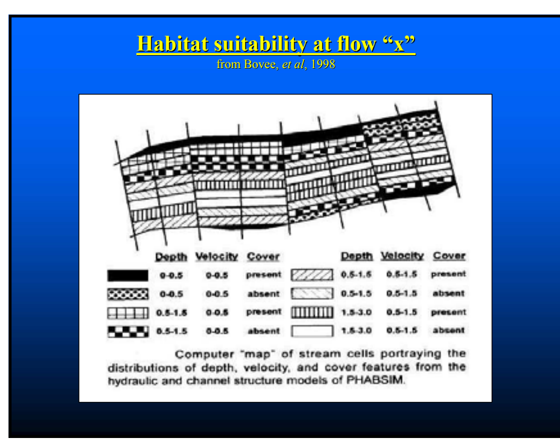
Calibration flows are gathered across the flow range of interest




This allows for a broad simulation flow range


Habitat Suitability Criteria for Depth
Suitability
Depth (ft)
Brook Trout
Brown Trout

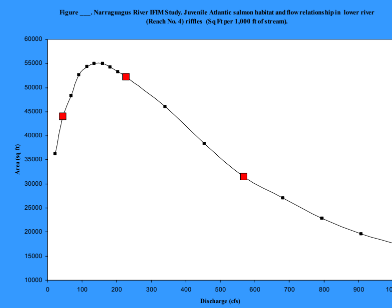

Habitat Suitability Criteria for Velocity
Brook Trout
Suitability
Velocity (ft/sec)
Adults
Fry


Habitat suitability at flow "x"
from Bovee, et al, 1998
Depth Velocity Cover
0-0.5 0-0.5 present
0-0.5 0-0.5 absent
0.5-1.5 0-0.5 present
0.5-1.5 0-0.5 absent
Depth Velocity Cover
0.5-1.5 0.5-1.5 present
0.5-1.5 0.5-1.5 absent
1.5-3.0 0.5-1.5 present
1.5-3.0 0.5-1.5 absent
Computer "map" of stream cells portraying the distributions of depth, velocity, and cover features from the hydraulic and channel structure models of PHABSIM.

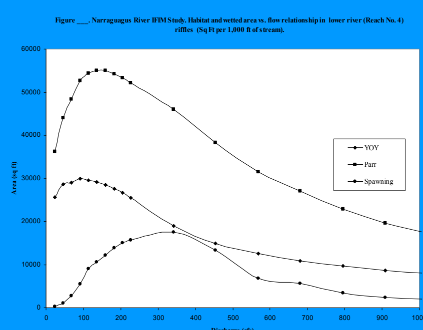
Weighted Usable Area

- ***WUA = the area of stream (per 1,000 linear ft) that is suitable habitat***
- WUA = wetted area of cell$_n$ *(sq ft) * SI (suitability index value)* + …… + wetted area of cell$_i$ * *SI (suitability index value)*
- SI = 1.0 is optimal, SI = 0.0 is unsuitable
- SI = (Si $_{depth}$) (Si $_{velocity}$) (Si $_{cover/substrate}$)

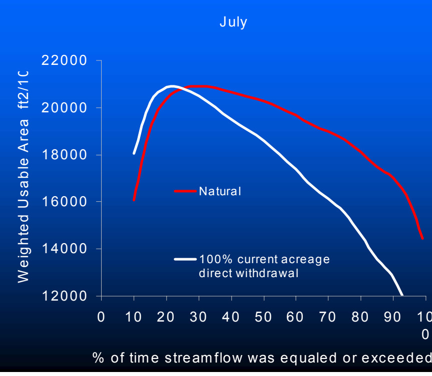
What comes OUT of a PHABSIM model ?

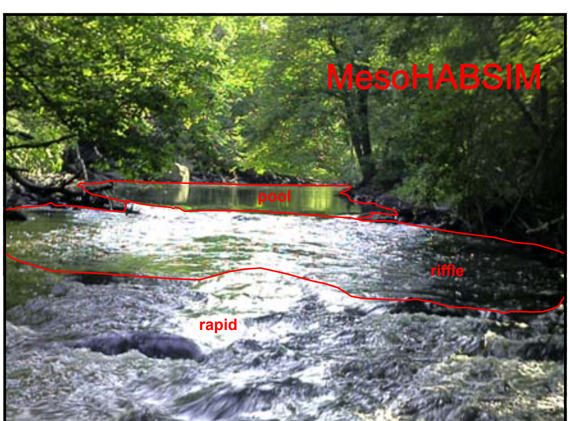


6. Compute Habitat Area at Each Flow



Examine effects of existing flow diversion on habitat

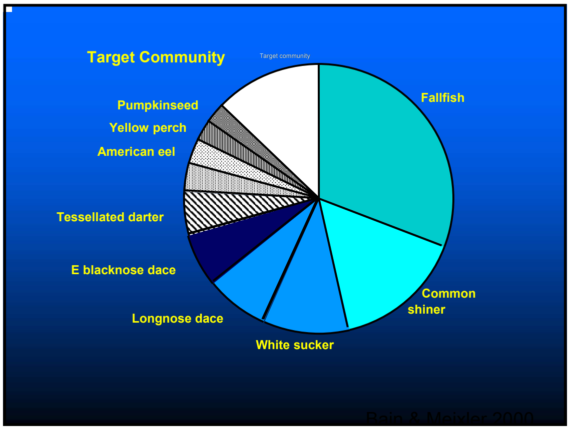


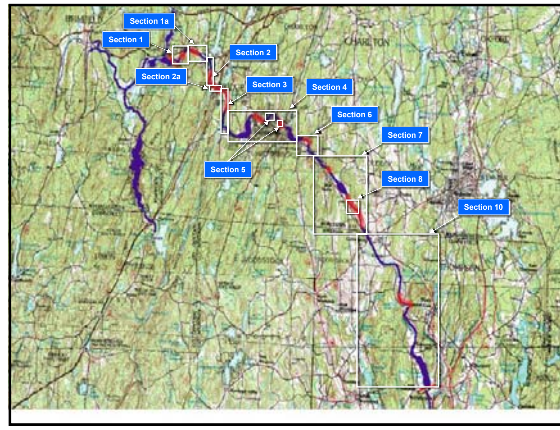


MesoHABSIM Hydro-morpological units*

- Riffle
- Rapid
- Cascade
- Glide
- Run
- Fast Run
- Pool
- Plunge Pool
- Backwater
- Side arm

* Modified from Bisson & Montgomery (1996), Doloff et al. (1993)





Establish of habitat selection criteria

- good quality rivers
- regionally valid set
- seasonal

Target community spawning criteria

Fish Species	Date	Temperature	Mesohabitat	Depth	Velocity	Substrate	Other
White Sucker	Late Spring	57-68F	Shallow water, Isolated Pools and riffles	Shallow <50cm	Swift/Flowing 10-45	Gravel/rocky Akal, micro, meso	
Common Shiner	May 1-July 15	60-65 F:15.5-18.3C	Shallow riffles	13-44mm (under 5)	Slow <=20	Gravel/S and Akal, psamal, micro	Likes to spawn over nests of other species
Fallfish	April 27-June 10	over 14.4C	Quiet pools	Shallow <50	Slow <=20	Gravel/small stones Akal, micro, meso	Eggs are covered by the parent with gravel
Longnose Dace	June and early July	11.7 C	Riffles, runs with gravel bottom	2-4inches (5-10cm) <15	Strong/Over 45 cm per second	Pebbles over 5cm Meso	Males guard territories, but no nest is built
Blacknose Dace	Late May-July	About 70F	Shallow riffles	4-8 inches <20	Fast water >45	Gravel Akal, micro	

FALLFISH

Presence (76%)		Beta
	BOULDER	1.95
	SHADING	-1.07
	DEPTH 0-25 cm	-1.76
	VELOCITY 45-60 cm/s	1.06
	RUN	-0.57
High abundance (60%)		
	Overhanging vegetation	-0.97

preference

COMMON SHINER

Presence (80%)		Beta
	BOULDER	1.71
	RIPRAP	1.40
	SHADING	-1.48
	DEPTH 50-75 cm	-1.23
High abundance (69%)		
	BOULDER	1.68
	SHADING	-1.01

WHITE SUCKER

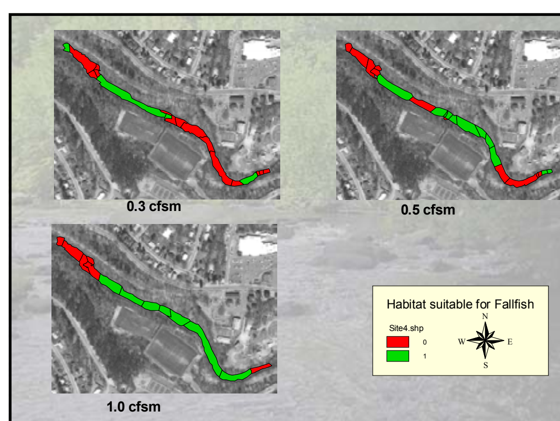
Presence (95%)		Beta
	DEPTH 75-100 cm	5.01
	DEPTH 50-75 cm	2.19
	MESOLITHAL (small cobble)	1.62
	UNDERCUT BANK	1.66
High abundance (66%)		
	Depth 75-100	7.62

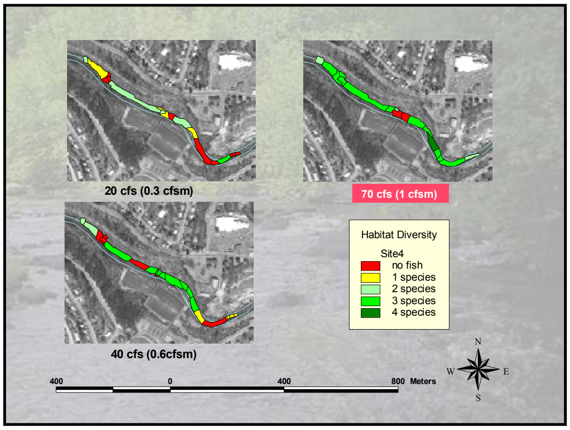
LONGNOSE DACE

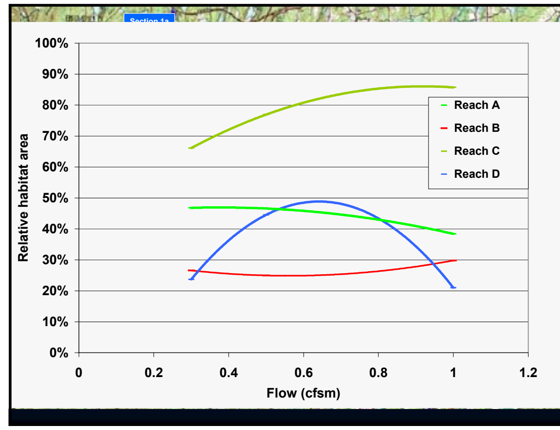
Presence (92%)		Beta
	RIFFLE	2.05
	FAST RUN	2.45
	XYLAL (wood)	4.60
	RIPRAP	2.29
High abundance (73%)		
	VELOCITY 45-60 cm/s	3.35

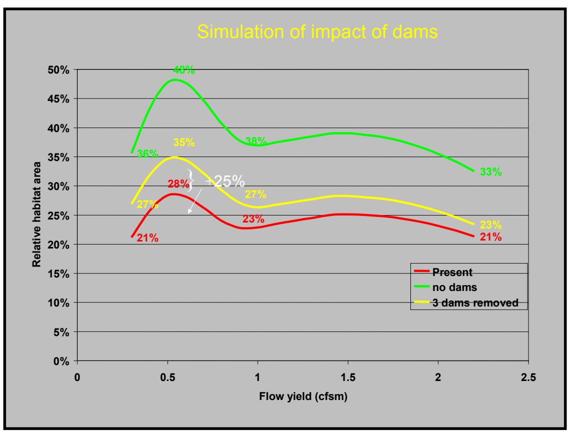
BLACKNOSE DACE

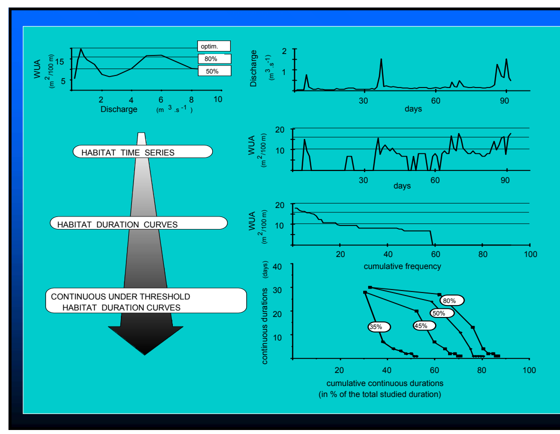
Presence (94%)		Beta
	DEPTH 0-25cm	3.03
	BOULDER	2.57
	SHADING	-1.44
	SHALLOW MARGIN	1.65
	PELAL (mud)	3.09
	VELOCITY 45-60 cm/s	1.46
	Submerged vegetation	-1.44
High abundance (79%)		
	MICROLITHAL (small gravel)	-4.20

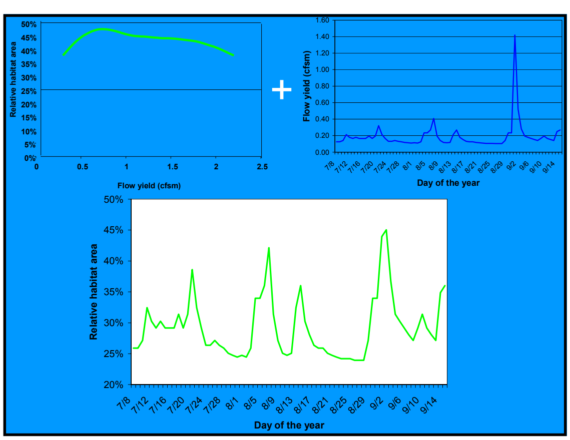


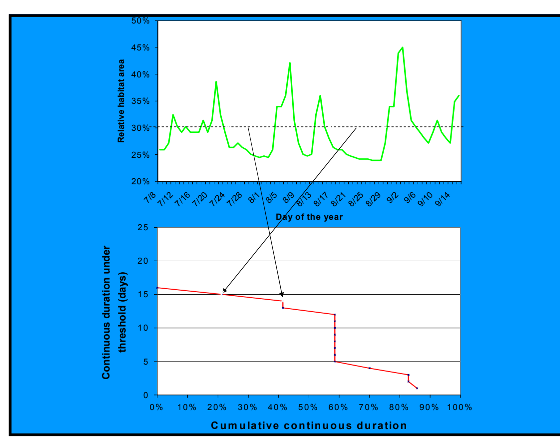

20 cfs (0.3 cfsm)
70 cfs (1 cfsm)
40 cfs (0.6cfsm)
Habitat Diversity
Site4
no fish
1 species
2 species
3 species
4 species
400 0 400 800 Meters
N
W
E
S


Relative habitat area
Flow (cfsm)
Reach A
Reach B
Reach C
Reach D

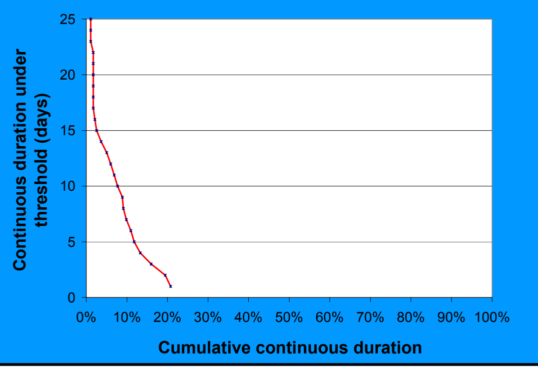

Simulation of impact of dams
Relative habitat area
Flow yield (cfsm)
48%
36%
38%
33%
35%
27%
28%
+25%
27%
23%
23%
21%
21%
Present
no dams
3 dams removed


WUA
optim.
80%
50%
Discharge
days
HABITAT TIME SERIES
HABITAT DURATION CURVES
CONTINUOUS UNDER THRESHOLD HABITAT DURATION CURVES
cumulative frequency
continuous durations
cumulative continuous durations
(in % of the total studied duration)

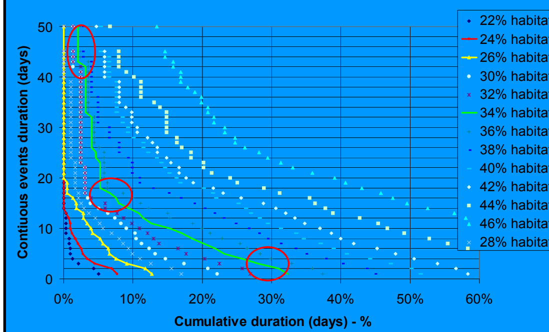

Relative habitat area
Flow yield (cfsm)
+
Flow yield (cfsm)
Day of the year
Relative habitat area
Day of the year


Relative habitat area
Day of the year
Continuous duration under threshold (days)
Cumulative continuous duration

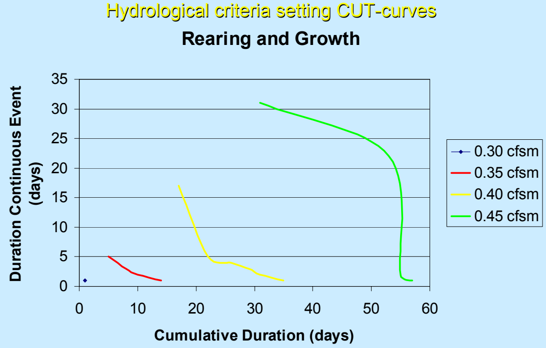
CUT curve 1949-1994



Habitat Continuous-Under-Threshold (CUT)-curves



Hydrological criteria setting CUT-curves



Developing a Target Fish Community to Assess Ecosystem Integrity

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Objectives

- Provide a Methodology for DFW to Describe the Characteristics of a Healthy, Stable River Fish Community (Realistic Expectation)
- Provide a Measurable Goal for Restoration

Developing a Target Fish Community

- Goal: “Define the fish community that is appropriate for a natural river in southern New England” (Bain and Meixler, 2000)
- Assumption: Biological Integrity should be Maintained and is defined by “a balanced, integrated, adaptive community” (Karr, 1991)
- Rivers Should Have River Fish Communities

Target Fish Community and Water Quality Standards

- Ipswich River "should resemble expected native fluvial-dominated fish community"
- Quinebaug River "community of fish appropriate for a natural river in Southern NE"

- CWA 101(a) …restore "biological integrity"
- integrity = condition where natural structure and function of ecosystems is maintained
- MAWQS: "Aquatic Life" = native, naturally diverse community of aquatic flora and fauna

Assessing Ecosystem Integrity

- Define the Expected Riverine (Target) Community
- Assess Current Community
- Compare Observed and Target

Habitat Use Categories (HUC's)

What is a River Fish?

- Fluvial Specialists- FS-(Require flowing Water - brook trout)
- Fluvial Dependents-FD- (Need flowing water at some time in their life cycle - white sucker)
- Macrohabitat Generalists-MG-(Don't require flowing water - largemouth bass)

Generalist or "Pond" Fish


Black Crappie


Largemouth Bass


Pumpkinseed

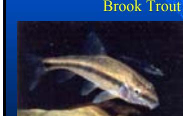

Bluegill


Yellow Perch

Fluvial or "River" Fish


Brook Trout


Fallfish


Creek Chubsucker


Tesselated Darter


Common Shiner

Habitat Use Class Examples

(Based on Bain, 1989)

- Largemouth Bass MG
- Bluegill MG
- White Sucker FD
- Slimy Sculpin FS
- Fallfish FS
- Longnose Dace FS
- Brook Trout FS

Develop Reference Condition

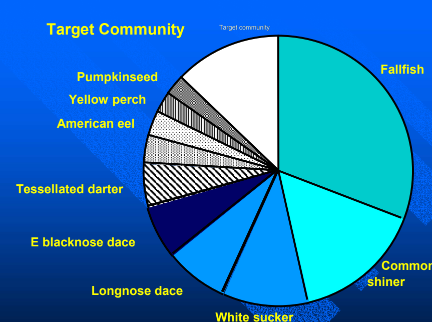
- Identify Species Most Common in Quality Rivers
- Most Common Species is Ranked #1, Second Most Common #2, etc.
- Convert Species Ranks to Expected Proportions
- Expected Proportions Used to Estimate Species Abundances in Target Community
- Expected Composition Shown by Species, Habitat Class and Pollution Tolerance

Fish species in reference river collections with their mean rank and expected contribution to the Quinebaug River community. Introduced species were deleted from the expected proportion values (dash entries) and the composition of the target community.

Species name	Ware River	Housatonic River	Willimantic River	Natchaug River	Fivemile River	Scantic River	Mean rank	Expected Proportion
American Eel			21	24	18	239	10	0.03
Brook Trout						12	20	0.01
Northern Pike				1			27	-
Chain Pickerel	8		7	9	29		16	0.02
Goldfish			3			21	18	-
Common Shiner	25		1440	19	691	342	2	0.15
Golden Shiner	1	1	22		26	11	17	0.02
Spottail Shiner	6		16			1	19	0.02
E Blacknose Dace	5	87	557	13	119	138	5	0.06
Longnose Dace	70	93		6	229	231	4	0.08
Creek Chub		14					15	0.02
Fallfish	226	1	3194	262	175	189	1	0.31
Common Carp		2					22	-
White Sucker	179	43	1092	91	70	131	3	0.10
Creek Chubsucker					1		28	0.01
Yellow Bullhead	2				8		23	-
Brown Bullhead			2	1	7	1	24	0.01
Rock Bass	11	7	10	15		11	14	-
Redbreast Sunfish			150	89	93	24	9	0.03
Green Sunfish			6	1			26	-
Pumpkinseed	36	1	50	22	17	7	13	0.02
Bluegill	6	1	12	91	147	33	7	-
Smallmouth Bass			226	78		1	11	-
Largemouth Bass	116	5	23	7	121	3	8	-
Black Crappie	3					3	25	-
Tessellated Darter	259		104	58	17	125	6	0.05
Yellow Perch	32	2	193	4	37	3	12	0.03
Sea Lamprey						12	20	0.01

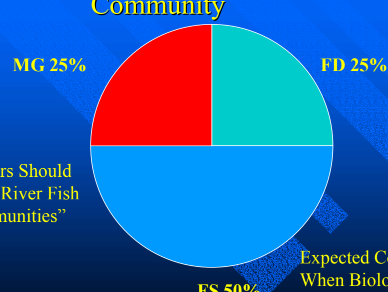
Quinebaug Target Fish Community

Species	Percent	HUC
Fallfish	31	FS
Common Shiner	15	FS
White Sucker	10	FD
Longnose Dace	8	FS
Blacknose Dace	6	FS
Tesselated Darter	5	FS



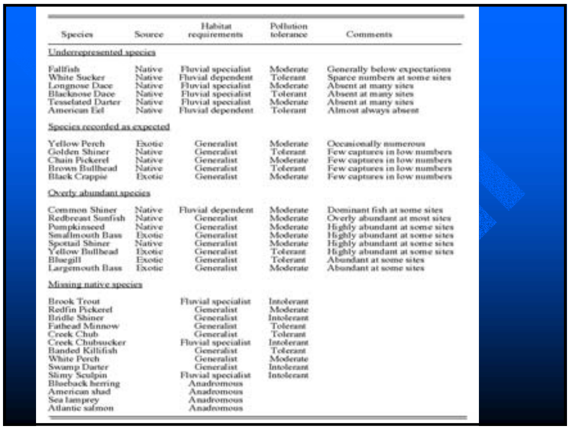
Bain & Meixler 2000

Quinebaug MainstemTarget Fish Community



"Rivers Should Have River Fish Communities"

Expected Condition When Biological Integrity is Maintained



Species	Source	Habitat requirements	Pollution tolerance	Comments
Underrepresented species				
Fallfish	Native	Fluvial specialist	Moderate	Generally below expectations
White Sucker	Native	Fluvial dependent	Tolerant	Sparce numbers at some sites
Longnose Dace	Native	Fluvial specialist	Moderate	Absent at many sites
Blacknose Dace	Native	Fluvial specialist	Tolerant	Absent at many sites
Tesselated Darter	Native	Fluvial specialist	Moderate	Absent at many sites
American Eel	Native	Fluvial dependent	Tolerant	Almost always absent
Species recorded as expected				
Yellow Perch	Exotic	Generalist	Moderate	Occasionally numerous
Golden Shiner	Native	Generalist	Tolerant	Few captures in low numbers
Chain Pickerel	Native	Generalist	Moderate	Few captures in low numbers
Brown Bullhead	Native	Generalist	Tolerant	Few captures in low numbers
Black Crappie	Exotic	Generalist	Moderate	Few captures in low numbers
Overly abundant species				
Common Shiner	Native	Fluvial dependent	Moderate	Dominant fish at some sites
Redbreast Sunfish	Native	Generalist	Moderate	Overly abundant at most sites
Pumpkinseed	Native	Generalist	Moderate	Highly abundant at some sites
Smallmouth Bass	Exotic	Generalist	Moderate	Highly abundant at some sites
Spottail Shiner	Native	Generalist	Moderate	Highly abundant at some sites
Yellow Bullhead	Exotic	Generalist	Tolerant	Highly abundant at some sites
Bluegill	Exotic	Generalist	Tolerant	Abundant at some sites
Largemouth Bass	Exotic	Generalist	Moderate	Abundant at some sites
Missing native species				
Brook Trout		Fluvial specialist	Intolerant	
Redfin Pickerel		Generalist	Moderate	
Bridle Shiner		Generalist	Intolerant	
Fathead Minnow		Generalist	Tolerant	
Creek Chub		Generalist	Tolerant	
Creek Chubsucker		Fluvial specialist	Intolerant	
Banded Killifish		Generalist	Tolerant	
White Perch		Generalist	Moderate	
Swamp Darter		Generalist	Intolerant	
Slimy Sculpin		Fluvial specialist	Intolerant	
Blueback herring		Anadromous		
American shad		Anadromous		
Sea lamprey		Anadromous		
Atlantic salmon		Anadromous